

WHAT IS CLAIMED IS:

1 1. A controller for generating an ON-time for a buck regulator receiving a
2 regulator input voltage and generating a regulated output voltage, said controller
3 comprising:

4 circuitry for sensing said regulated output voltage and generating a sensed
5 output voltage proportional to said regulated output voltage;

6 circuitry for adding a first voltage ramp to said sensed output voltage to
7 generate a modified sensed output voltage;

8 circuitry for adding a second voltage ramp to a first reference voltage to
9 generate a ripple reference voltage;

10 circuitry for processing said ripple reference voltage to generate a modified
11 reference voltage;

12 circuitry for comparing said modified sensed output voltage to said modified
13 reference voltage generating a comparator output having a first logic state when said
14 modified sensed output voltage is greater than said modified reference voltage and a
15 second logic state when said modified sensed output voltage is less than said
16 modified reference voltage; and

17 circuitry for generating a control signal having a first logic state during said
18 ON-time in response to said comparator output, said regulator input voltage and a
19 second reference voltage, wherein said regulated output voltage receives energy
20 directly from said regulator input voltage during said ON-time and said regulated
21 output voltages receives stored energy from said regulator input voltage after said
22 ON-time terminates.

1 2. The controller of claim 1, wherein said first and second voltage ramps are
2 generated in response to a common voltage ramp and are substantially equal.

1 3. The controller of claim 2, wherein said circuitry for processing said ripple
2 reference voltage comprises:

3 circuitry for sampling and tracking said ripple reference voltage when said
4 ON-time has terminated; and

5 circuitry for holding a value of said ripple reference voltage as said modified
6 reference voltage during said ON-time.

1 4. The controller of claim 3, wherein said second reference voltage is
2 substantially equal to said first reference voltage.

1 5. The controller of claim 4 further comprising a ramp circuit for generating said
2 common ramp voltage in response to a load current of said regulated output voltage
3 flowing in a sense resistance.

1 6. The controller of claim 5, wherein said sense resistance corresponds to a sense
2 resistor in series with said regulated output voltage.

1 7. The controller of claim 5, wherein said sense resistance corresponds to a
2 switch resistance of a first electronic switch that is gated OFF when said ON-time
3 starts and is gated ON when said ON-time has terminated, wherein said first
4 electronic switch conducts said load current when gated ON.

1 8. The controller of claim 4 further comprising a ramp circuit for generating said
2 common ramp voltage in response to charging a capacitor with a constant current
3 when said ON-time has terminated and discharging said capacitor during said ON-
4 time.

1 9. The controller of claim 8, wherein said circuitry for adding said first voltage
2 ramp to said sensed output voltage comprises:

3 a first resistor having a first terminal coupled to said sensed output voltage
4 and a second terminal; and

5 a voltage-to-current converter having an input coupled to said control voltage
6 ramp, a first output generating a first current ramp, and a second output generating a
7 second current ramp, wherein said first output is coupled to said second terminal of
8 said first resistor and said modified sensed output voltage is generated at said second
9 terminal in response to said first current ramp flowing in said first resistor.

1 10. The controller of claim 9, wherein said circuitry for adding said second
2 voltage ramp to said first reference voltage comprises a second resistor having a first
3 terminal coupled to said first reference voltage and a second terminal coupled to said
4 second output of said voltage to current converter, wherein said ripple reference
5 voltage is generated at said second terminal of said second resistor in response to said
6 second current ramp flowing in said second resistor.

1 11. The controller of claim 9, wherein said voltage-to-current converter comprises
2 two transconductance amplifiers having a common input coupled to said control
3 voltage ramp, said first output generating said first current ramp, and second output
4 generating said second current ramp.

1 12. The controller of claim 9, wherein said voltage-to-current converter is a
2 current mirror circuit.

1 13. The controller of claim 6, wherein said circuitry for adding said first voltage
2 ramp to said sensed output voltage comprises:

3 a first resistor having a first terminal coupled to said sensed output voltage
4 and a second terminal; and

5 a voltage-to-current converter having an input coupled to said control voltage
6 ramp, a first output generating a first current ramp, and a second output generating a
7 second current ramp, wherein said first output is coupled to said second terminal of
8 said first resistor and said modified sensed output voltage is generated at said second
9 terminal of said first resistor in response to said first current ramp flowing in said first
10 resistor.

1 14. The controller of claim 13, wherein said circuitry for adding said second
2 voltage ramp to said first reference voltage comprises a second resistor having a first
3 terminal coupled to said first reference voltage and a second terminal coupled to said
4 second output of said voltage-to-current converter, wherein said ripple reference
5 voltage is generated at said second terminal of said second resistor in response to said
6 second current ramp flowing in said second resistor.

1 15. The controller of claim 13, wherein said voltage-to-current converter
2 comprises two transconductance amplifiers having a common input coupled to said
3 control voltage ramp, said first output generating said first current ramp, and second
4 output generating said second current ramp.

1 16. The controller of claim 7, wherein said ramp circuit comprises:

2 circuitry for sampling and tracking a voltage across said sense resistance when
3 said ON-time has terminated; and

4 circuitry for holding a value of said voltage across said sense resistance as
5 said control ramp voltage during said ON-time.

1 17. The controller of claim 16, wherein said circuitry for adding said first voltage
2 ramp to said sensed output voltage comprises:

3 3. a first resistor having a first terminal coupled to said sensed output voltage
4 and a second terminal; and

5 5. a voltage-to-current converter having an input coupled to said control voltage
6 ramp, a first output generating a first current ramp, and a second output generating a
7 second current ramp, wherein said first output is coupled to said second terminal and
8 said modified sensed output voltage is generated at said second terminal of said first
9 resistor in response to said first current ramp flowing in said first resistor.

1 18. The controller of claim 17, wherein said circuitry for adding said second
2 voltage ramp to said first reference voltage comprises a second resistor having a first
3 terminal coupled to said first reference voltage and a second terminal coupled to said
4 second output of said voltage to current converter, wherein said ripple reference
5 voltage is generated at said second terminal of said second resistor in response to said
6 second current ramp flowing in said second resistor.

1 19. The controller of claim 17, wherein said voltage-to-current converter
2 comprises two transconductance amplifiers having a common input coupled to said
3 control voltage ramp, said first output generating said first current ramp and second
4 output generating said second current ramp.

1 20. The controller of claim 2, wherein said circuitry for processing said ripple
2 reference voltage comprises a low pass filter circuit having an input coupled to said
3 ripple reference voltage and an output generating said modified reference voltage.

- 1 21. The controller of claim 20, wherein said first reference voltage is generated by
2 an offset circuit comprising:
 - 3 a differential transconductance amplifier having a positive input coupled to
4 said regulated output voltage, a negative input coupled to said second reference
5 voltage, and generating a reference current output as a gain times a difference
6 between said regulated output voltage and said second reference voltage, wherein said
7 reference current is coupled to a capacitor that integrates said reference current
8 generating said first reference voltage.
- 1 22. The controller of claim 21, further comprising a ramp circuit for generating a
2 first control ramp voltage in response to a load current of said regulated output
3 voltage flowing in a sense resistance.
- 1 23. The controller of claim 22, wherein said sense resistance corresponds to a
2 switch resistance of a first electronic switch that is gated OFF when said ON-time
3 starts and is gated ON when said ON-time has terminated, wherein said first
4 electronic switch conducts said load current when gated ON.
- 1 24. The controller of claim 23, wherein said ramp circuit comprises:
 - 2 circuitry for sampling and tracking a voltage across said sense resistance when
3 said ON-time has terminated; and
 - 4 circuitry for holding a value of said voltage across said sense resistance as
5 said control ramp voltage during said ON-time.

1 25. The controller of claim 24, wherein said circuitry for adding said first voltage
2 ramp to said sensed output voltage comprises:

3 a first resistor having a first terminal coupled to said sensed output voltage
4 and a second terminal; and

5 a first voltage-to-current converter having an input coupled to said first
6 control voltage ramp, a first output generating a first current ramp, and a second
7 output generating a second current ramp, wherein said first output is coupled to said
8 second terminal of said first resistor and said modified sensed output voltage is
9 generated at said second terminal in response to said first current ramp flowing in said
10 first resistor.

1 26. The controller of claim 25, wherein said circuitry for adding said second
2 voltage ramp to said first reference voltage comprises a second resistor having a first
3 terminal coupled to said first reference voltage and a second terminal coupled to said
4 second output of said voltage to current converter, wherein said ripple reference
5 voltage is generated at said second terminal of said second resistor in response to said
6 second current ramp flowing in said second resistor.

1 27. The controller of claim 25, wherein said voltage-to-current converter
2 comprises two transconductance amplifiers having a common input coupled to said
3 control voltage ramp, said first output generating said first current ramp, and second
4 output generating said second current ramp.

1 28. The controller of claim 27 further comprising:
2 circuitry for adding a third voltage ramp to said sensed output voltage; and
3 circuitry for adding a fourth voltage ramp to said first reference voltage.

1 29. The controller of claim 28 further comprising a second ramp circuit for
2 generating a second control ramp voltage in response to charging a capacitor with a
3 constant current when said ON-time has terminated, wherein said capacitor is
4 discharged during said ON-time.

1 30. The controller of claim 29, wherein said circuitry for adding said third voltage
2 ramp to said sensed output voltage further comprises a second voltage-to-current
3 converter having an input coupled to said second control voltage ramp, a third output
4 generating a third current ramp, and a fourth output generating a fourth current ramp,
5 wherein said third output is coupled to said second terminal of said first resistor,
6 wherein said modified sensed output voltage is further modified in response to said
7 third current ramp flowing in said first resistor.

1 31. The controller of claim 30, wherein said circuitry for adding said fourth
2 voltage ramp to said first reference voltage further comprises coupling said fourth
3 output said second terminal of said second resistor, wherein said modified reference
4 voltage is further modified in response to said fourth current ramp flowing in said
5 second resistor.

1 32. The controller of claim 30, wherein said voltage-to-current converter
2 comprises two transconductance amplifiers having a common input coupled to said
3 control voltage ramp, said first output generating said first current ramp, and second
4 output generating said second current ramp.

1 33. A system comprising:

2 a processor;

3 a memory for storing instructions and data for said processor;

4 a display interface for coupling signals from said processor to a display

5 device;

6 a user interface for coupling signals from a user to said processor; and

7 a buck regulator receiving a regulator input voltage and generating a regulated

8 output voltage for said system, an ON-time of said buck regulator controlled by a

9 constant ON-time controller having;

10 circuitry for sensing said regulated output voltage and generating a sensed

11 output voltage proportional to said regulated output voltage;

12 circuitry for adding a first voltage ramp to said sensed output voltage to

13 generate a modified sensed output voltage;

14 circuitry for adding a second voltage ramp to a first reference voltage to

15 generate a ripple reference voltage;

16 circuitry for processing said ripple reference voltage to generate a modified

17 reference voltage;

18 circuitry for comparing said modified sensed output voltage to said modified

19 reference voltage generating a comparator output having a first logic state when said

20 modified sensed output voltage is greater than said modified reference voltage and a

21 second logic state when said modified sensed output voltage is less than said

22 modified reference voltage; and

23 circuitry for generating a control voltage having a first logic state during said

24 ON-time in response to said comparator output, said regulator input voltage and a

25 second reference voltage, wherein said regulated output voltage receives energy

26 directly from said regulator input voltage during said ON-time and said regulated

27 output voltages receives stored energy from said regulator input voltage after said
28 ON-time terminates.

1 34. The system of claim 33, wherein said first and second voltage ramps are
2 generated in response to a common voltage ramp and are substantially equal.

1 35. The system of claim 34, wherein said circuitry for processing said ripple
2 reference voltage comprises:

3 circuitry for sampling and tracking said ripple reference voltage when said
4 ON-time has terminated; and

5 circuitry for holding a value of said ripple reference voltage as said modified
6 reference voltage during said ON-time.

1 36. The system of claim 35, wherein said second reference voltage is substantially
2 equal to said first reference voltage.

1 37. The system of claim 36 further comprising a ramp circuit for generating said
2 common ramp voltage in response to a load current of said regulated output voltage
3 flowing in a sense resistance.

1 38. The system of claim 37, wherein said sense resistance corresponds to a sense
2 resistor in series with said regulated output voltage.

1 39. The system of claim 37, wherein said sense resistance corresponds to a switch
2 resistance of a first electronic switch that is gated OFF when said ON-time starts and
3 is gated ON when said ON-time has terminated, wherein said first electronic switch
4 conducts said load current when gated ON.

1 40. The system of claim 36 further comprising a ramp circuit for generating said
2 common ramp voltage in response to charging a capacitor with a constant current
3 when said ON-time has terminated and discharging said capacitor during said ON-
4 time.

1 41. The system of claim 40, wherein said circuitry for adding said first voltage
2 ramp to said sensed output voltage comprises:

3 a first resistor having a first terminal coupled to said sensed output voltage
4 and a second terminal; and

5 a voltage-to-current converter having an input coupled to said control voltage
6 ramp, a first output generating a first current ramp, and a second output generating a
7 second current ramp, wherein said first output is coupled to said second terminal of
8 said first resistor and said modified sensed output voltage is generated at said second
9 terminal in response to said first current ramp flowing in said first resistor.

1 42. The system of claim 41, wherein said circuitry for adding said second voltage
2 ramp to said first reference voltage comprises a second resistor having a first terminal
3 coupled to said first reference voltage and a second terminal coupled to said second
4 output of said voltage to current converter, wherein said ripple reference voltage is
5 generated at said second terminal of said second resistor in response to said second
6 current ramp flowing in said second resistor.

1 43. The system of claim 41, wherein said voltage-to-current converter comprises
2 two transconductance amplifiers having a common input coupled to said control
3 voltage ramp, said first output generating said first current ramp, and second output
4 generating said second current ramp.

1 44. The system of claim 41, wherein said voltage-to-current converter is a current
2 mirror circuit.

1 45. The system of claim 38, wherein said circuitry for adding said first voltage
2 ramp to said sensed output voltage comprises:

3 a first resistor having a first terminal coupled to said sensed output voltage
4 and a second terminal; and

5 a voltage-to-current converter having an input coupled to said control voltage
6 ramp, a first output generating a first current ramp, and a second output generating a
7 second current ramp, wherein said first output is coupled to said second terminal of
8 said first resistor and said modified sensed output voltage is generated at said second
9 terminal of said first resistor in response to said first current ramp flowing in said first
10 resistor.

1 46. The system of claim 45, wherein said circuitry for adding said second voltage
2 ramp to said first reference voltage comprises a second resistor having a first terminal
3 coupled to said first reference voltage and a second terminal coupled to said second
4 output of said voltage-to-current converter, wherein said ripple reference voltage is
5 generated at said second terminal of said second resistor in response to said second
6 current ramp flowing in said second resistor.

1 47. The system of claim 45, wherein said voltage-to-current converter comprises
2 two transconductance amplifiers having a common input coupled to said control
3 voltage ramp, said first output generating said first current ramp, and second output
4 generating said second current ramp.

- 1 48. The system of claim 39, wherein said ramp circuit comprises:
2 circuitry for sampling and tracking a voltage across said sense resistance when
3 said ON-time has terminated; and
4 circuitry for holding a value of said voltage across said sense resistance as
5 said control ramp voltage during said ON-time.
- 1 49. The system of claim 48, wherein said circuitry for adding said first voltage
2 ramp to said sensed output voltage comprises:
3 a first resistor having a first terminal coupled to said sensed output voltage
4 and a second terminal; and
5 a voltage-to-current converter having an input coupled to said control voltage
6 ramp, a first output generating a first current ramp, and a second output generating a
7 second current ramp, wherein said first output is coupled to said second terminal and
8 said modified sensed output voltage is generated at said second terminal of said first
9 resistor in response to said first current ramp flowing in said first resistor.
- 1 50. The system of claim 49, wherein said circuitry for adding said second voltage
2 ramp to said first reference voltage comprises a second resistor having a first terminal
3 coupled to said first reference voltage and a second terminal coupled to said second
4 output of said voltage to current converter, wherein said ripple reference voltage is
5 generated at said second terminal of said second resistor in response to said second
6 current ramp flowing in said second resistor.
- 1 51. The system of claim 49, wherein said voltage-to-current converter comprises
2 two transconductance amplifiers having a common input coupled to said control
3 voltage ramp, said first output generating said first current ramp and second output
4 generating said second current ramp.

1 52. The system of claim 34, wherein said circuitry for processing said ripple
2 reference voltage comprises a low pass filter circuit having an input coupled to said
3 ripple reference voltage and an output generating said modified reference voltage.

1 53. The system of claim 52, wherein said first reference voltage is generated by an
2 offset circuit comprising:

3 a differential transconductance amplifier having a positive input coupled to
4 said regulated output voltage, a negative input coupled to said second reference
5 voltage, and generating a reference current output as a gain times a difference
6 between said regulated output voltage and said second reference voltage, wherein said
7 reference current is coupled to a capacitor that integrates said reference current
8 generating said first reference voltage.

1 54. The system of claim 53 further comprising a ramp circuit for generating a first
2 control ramp voltage in response to a load current of said regulated output voltage
3 flowing in a sense resistance.

1 55. The system of claim 54, wherein said sense resistance corresponds to a switch
2 resistance of a first electronic switch that is gated OFF when said ON-time starts and
3 is gated ON when said ON-time has terminated, wherein said first electronic switch
4 conducts said load current when gated ON.

1 56. The system of claim 55, wherein said ramp circuit comprises:
2 circuitry for sampling and tracking a voltage across said sense resistance when
3 said ON-time has terminated; and
4 circuitry for holding a value of said voltage across said sense resistance as
5 said control ramp voltage during said ON-time.

1 57. The system of claim 56, wherein said circuitry for adding said first voltage
2 ramp to said sensed output voltage comprises:

3 a first resistor having a first terminal coupled to said sensed output voltage
4 and a second terminal; and

5 a first voltage-to-current converter having an input coupled to said first
6 control voltage ramp, a first output generating a first current ramp, and a second
7 output generating a second current ramp, wherein said first output is coupled to said
8 second terminal of said first resistor and said modified sensed output voltage is
9 generated at said second terminal in response to said first current ramp flowing in said
10 first resistor.

1 58. The system of claim 57, wherein said circuitry for adding said second voltage
2 ramp to said first reference voltage comprises a second resistor having a first terminal
3 coupled to said first reference voltage and a second terminal coupled to said second
4 output of said voltage to current converter, wherein said ripple reference voltage is
5 generated at said second terminal of said second resistor in response to said second
6 current ramp flowing in said second resistor.

1 59. The system of claim 57, wherein said voltage-to-current converter comprises
2 two transconductance amplifiers having a common input coupled to said control
3 voltage ramp, said first output generating said first current ramp, and second output
4 generating said second current ramp.

1 60. The system of claim 59 further comprising:

2 circuitry for adding a third voltage ramp to said sensed output voltage; and
3 circuitry for adding a fourth voltage ramp to said first reference voltage.

1 61. The system of claim 60 further comprising a second ramp circuit for
2 generating a second control ramp voltage in response to charging a capacitor with a
3 constant current when said ON-time has terminated, wherein said capacitor is
4 discharged during said ON-time.

1 62. The system of claim 61, wherein said circuitry for adding said third voltage
2 ramp to said sensed output voltage further comprises a second voltage-to-current
3 converter having an input coupled to said second control voltage ramp, a third output
4 generating a third current ramp, and a fourth output generating a fourth current ramp,
5 wherein said third output is coupled to said second terminal of said first resistor,
6 wherein said modified sensed output voltage is further modified in response to said
7 third current ramp flowing in said first resistor.

1 63. The system of claim 62, wherein said circuitry for adding said fourth voltage
2 ramp to said first reference voltage further comprises coupling said fourth output said
3 second terminal of said second resistor, wherein said modified reference voltage is
4 further modified in response to said fourth current ramp flowing in said second
5 resistor.

1 64. The system of claim 62, wherein said voltage-to-current converter comprises
2 two transconductance amplifiers having a common input coupled to said control
3 voltage ramp, said first output generating said first current ramp, and second output
4 generating said second current ramp.